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STREAMFLOW NITROGEN LOSS FOLLOWING FOREST EROSION CONTROL FERTILIZATION

by

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Abstract

Three gaged watersheds, approximately 500 hectares in size, in north central Washington were severely burned in 1970 by wildfire. In an experimental erosion control seeding program, two watersheds were fertilized, one with urea and the other with ammonium sulfate. The third watershed was retained as an unrehabilitated control. For a 60-day period during and following fertilization, 1.37 kilograms of urea-N and 2.90 kilograms of nitrate-N were estimated to have been carried by streamflow from the watershed fertilized with 27.5 metric tons of elemental nitrogen as urea. On the watershed fertilized with 33.16 metric tons of elemental nitrogen as ammonium sulfate, 1.45 kilograms of nitrate-N was estimated to have been transported from the watershed by streamflow.

Keywords: Aerial fertilization, streamflow records, soil erosion.

INTRODUCTION

Forest fertilization is becoming an operational practice in many areas of the United States. Scientists have been attempting to monitor the fate of this chemical addition to the forest environment (Moore 1970). In recent years, fertilization to enhance early devel-

opment of introduced and native vegetation (Klock 1969) after wildfire has become an accepted practice in the Cascade Mountains of Washington.

Considerable concern has been expressed over the possible effect on water quality by fertilization during erosion control (Stanford et al. 1970). In forest fertilization for wood production, the application of chemicals in a zone near stream channels can be avoided to prevent both significant chemical loss and the possible deterioration of water quality. Protection of this zone near streams with vegetative cover is most important in forest erosion control. Since fertilizing to develop satisfactory vegetative cover and maintain soil stability appears imperative in many Cascade Mountain watersheds, information is needed on the fertilizer carried by streamflow from watersheds during and following erosion control.

On August 24, 1970, the entire 1,551-hectare Entiat Experimental Forest in north central Washington was severely burned by wildfire. Since the soils are quite infertile and unstable in this important water-producing region, reseeding and fertilization appeared necessary. Thus, a unique opportunity was created to run a controlled test on three gaged watersheds.

STUDY AREA

The Entiat Experimental Forest was set aside in 1957 as a study area representative of much of the forested lands east of the Washington Cascade Mountain crest (Berndt 1971). It is made up of three adjacent watersheds: Fox Creek, Burns Creek, and McCree Creek--473, 564, and 514 hectares in size, respectively, on a generally southwest aspect.

The study area watersheds are within the Entiat River basin, an area characterized by steep and rugged relief dissected by numerous tributary streams. The river valley is the characteristic U-shape of a glacial valley, having been formed by two glacial advances and recessions during the Wisconsin stage of the Pleistocene epoch.[1/] The watersheds, which were relatively unaffected by the glaciation, were left as hanging valleys above the main valley floor. Watershed elevations range from 550 meters to more than 2,100 meters at the headwaters. Mean slope is about 50 percent but slopes as steep as 90 percent are common.

[1/] B. M. Page. Geology of a part of the Chiwaukum quadrangle. 1939. (Unpublished Ph. D. thesis on file at Stanford Univ., Palo Alto, Calif.)

The base rock on the watersheds is an extensive formation known as the Chelan Batholith, a mesozoic intrusive granodiorite with biotite and hornblende as accessory minerals. A medium- to coarse-grained massive rock, the gray granodiorite weathers deeply where exposed. Since glaciation, the area has been periodically covered by volcanic ash and pumice, mostly originating from Glacier Peak (Fryxell 1965) approximately 33 kilometers west-northwest of the study area.

The Choral soil series occupies about 55 percent of the area (Iritani and Meyer 1967). Rampart soils occupy another 30 percent, and rock land or rock outcrops account for 15 percent. Choral soils are well drained, moderately coarse-textured, and derived from volcanic ash and pumice. The surface 60 centimeters is a fine, sandy loam grading to coarse, loamy sand. This is underlain by pure pumice up to 6 meters deep. Rampart soils are very similar to Choral except they occur at lower elevations and have developed under warmer climatic conditions. Total nitrogen levels of surface soils for both are normally below 0.05 percent. Since the fire, considerable carbonized plant material (ash) covers the soil surface, particularly in the stream zones.

Vegetation destroyed by the fire was almost entirely mature virgin forest. Ponderosa pine (*Pinus ponderosa* Laws.) was the main species with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) as the main associated species. Stocking densities ranged from medium to poor. Common understory species were snowbrush ceanothus (*Ceanothus velutinus* Dougl.), bitterbrush (*Purshia tridentata* (Pursh) DC.), grouse whortleberry (*Vaccinium scoparium* Leib.), and pinegrass (*Calamagrostis rubescens* Buckl.).

The climate is typical of the region with droughty summers and most of the precipitation falling as snow in the winter months. Available records show, at 915-meter elevation, an annual mean temperature of 6.8° C. and an average annual precipitation of 46 centimeters.

Stream channels on all three watersheds are deeply incised and contain quantities of fire debris and decaying logs. Estimated channel lengths for Fox, Burns, and McCree are 3.5, 5.3, and 6.9 kilometers, respectively. Streamflow is characterized by high volumes from snowmelt in May and June with a rapid decline to a low and fairly steady flow by August or September. Streamflow ranges between a low and a high of 0.011 and 0.396 liters per hectare (0.1 to 3.5 cubic feet per square mile).

METHOD

An experimental rehabilitation plan for erosion control was developed and initiated in which Fox Creek watershed was left undisturbed as a control stream. Burns Creek watershed was seeded with a grass mixture and fertilized with 280 kilograms per hectare of ammonium sulfate--a total application of 157.92 metric tons of fertilizer which included 33.16 metric tons of elemental nitrogen. Burns Creek watershed was fertilized in two periods, October 30-31 (21.5 metric tons) and November 9-12 (136.42 metric tons).

McCree Creek watershed was also seeded with a grass mixture and fertilized with 117.6 kilograms per hectare urea--a total application of 59.8 metric tons of fertilizer material which included 27.5 metric tons of elemental nitrogen. Urea was spread in three periods: October 30-31 (4.5 metric tons), November 4-5 (14.5 metric tons), and November 7-8 (40.8 metric tons).

All fertilizer was spread by helicopters with 250-kilogram loads on a grid approximately 24 meters wide. No attempt was made to avoid stream channels.

At the outflow of all three watersheds 4-liter water samples were collected two times before fertilization (October 23 and 29), every 12 hours (0900 and 2100 hours) during the period of fertilization (October 30 to November 12), daily from November 13 to 20, and on November 25, December 1, 7, 10, and 17. Water samples were taken to the laboratory, keeping the sample at or below stream temperature of about 5° C. and stored unfrozen at -0.6° C. until chemical analysis was done.

Urea-N concentrations in the stream water samples were determined by the method proposed by Newell et al. (1967) and modified for fresh water by Moore.[2/] Nitrate-N was determined by the cadmium-copper reduction method proposed by Wood et al. (1967) and again modified by Moore. Ammonia-N was analyzed by the Nessler method (Chapman and Pratt 1961).

RESULTS

In the 8 days prior to fertilization, no measurable levels of ammonia-, urea-, or nitrate-N were detected in Burns or McCree Creek. At the beginning of the sampling period October 23, Fox Creek had a

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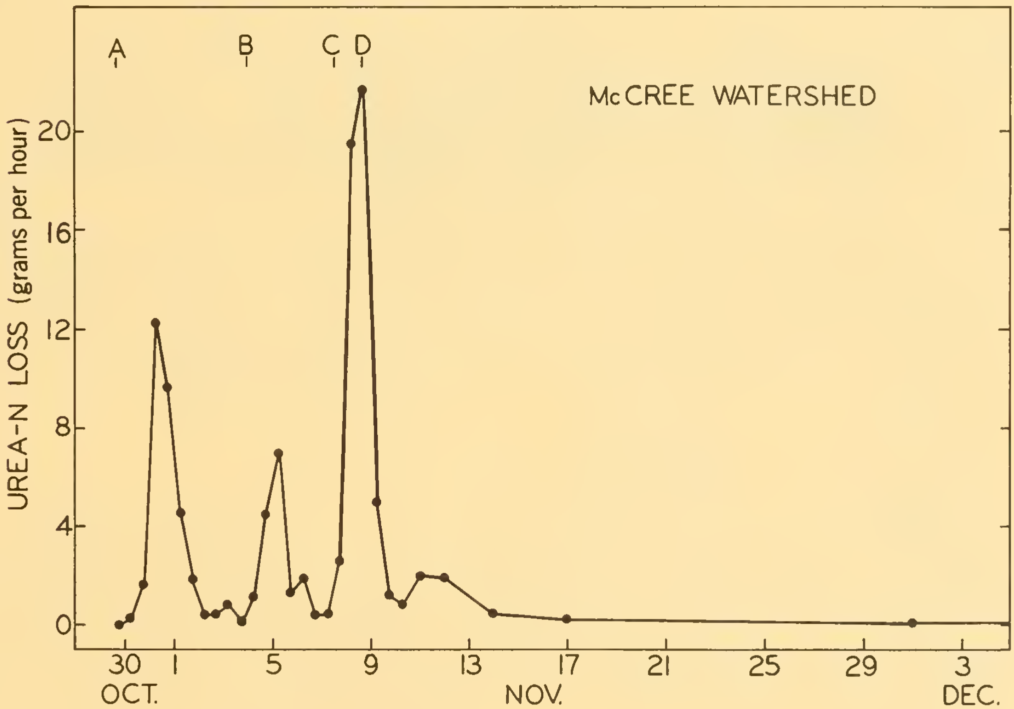
[2/] Personal communication with D. G. Moore. Forest Sci. Lab., Pac. Northwest Forest & Range Exp. Sta., Corvallis, Oreg.

urea-N level of 35 parts per billion, with wildlife activity a possible source. This level decreased until it was undetectable after November 11. No ammonia-N or nitrate-N was detected in Fox Creek during the period of analysis October 23 to December 17, 1970.

The three distinct periods of aerial fertilization activity on the McCree Creek watershed (October 30-31, November 4, and November 7-8) were evident in the stream water analysis. Each fertilization period was identified by a marked increase in urea-N as shown in figure 1. The maximum urea-N carried in the stream after each

Figure 1.--*Streamflow urea-nitrogen loss from McCree Creek watershed after fertilization with 59.8 metric tons of urea.* A, B, *and* C, *three periods of fertilization;* D, *period of highest loss.*



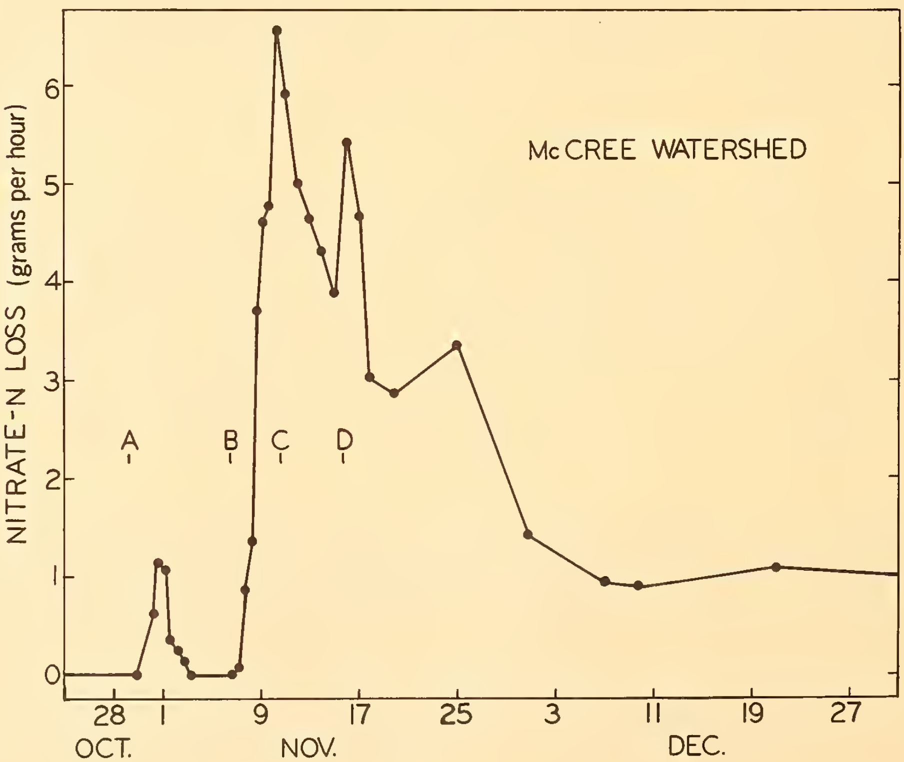
fertilization period was 12.25, 6.89, and 21.71 grams per hour (355, 185, and 616 parts per billion). The urea-N outflow rate dropped rapidly after the end of the third fertilization period (November 8) and became nondetectable on December 1. Streamflow during the period October 3 through December 31 ranged from 8.2 to 10.3 liters per second (0.29 to 0.36 cubic foot per second), with the exception of short duration peak flows of 17.3 liters per second on November 8

following a short period of heavy precipitation the evening of November 7 and 11.04 liters per second on November 16, again after a short period of rain. Flow rates returned to the average within 24 hours after these two peak flow rates. Total weight of urea-N transported by streamflow from the watershed during the period October 30 to December 1 was estimated at 1.37 kilograms.

No ammonia-N was measurable in McCree Creek during the sampling period. Minimum measurable level of ammonia-N was 0.2 parts per million.

After the first fertilization period on McCree Creek watershed October 30-31, the nitrate-N carried in the stream rose from nondetectable levels to a peak of 1.14 grams per hour (53 parts per billion concentrate). This peak was at 0900 hours, November 1 (fig. 2). Nitrate-N returned to nondetectable levels at 2100 hours, Novem-

Figure 2.--*Streamflow nitrate-nitrogen loss from McCree Creek watershed after fertilization with urea.* A *and* B, *first and third period of fertilization;* C, *period of highest loss; and* D, *secondary peak loss associated with precipitation activity.*



ber 3 and remained there until 2100 hours, November 7. The third and heaviest fertilization period was November 7-8. The level of nitrate-N transported by the stream again rose very rapidly and reached a maximum level of 6.56 grams per hour (210 parts per billion concentrate) at 2100 hours, November 10. High levels of nitrate were also recorded on November 16 after a short period of rain and on November 25. No reason for the high level on November 25 was observed. Nitrate-N streamflow levels decreased to a nearly constant 1 gram per hour after December 7, 1 month following fertilization. For the period October 31 to December 31, 2.90 kilograms of nitrate-N was estimated to have been carried by streamflow from the McCree Creek watershed.

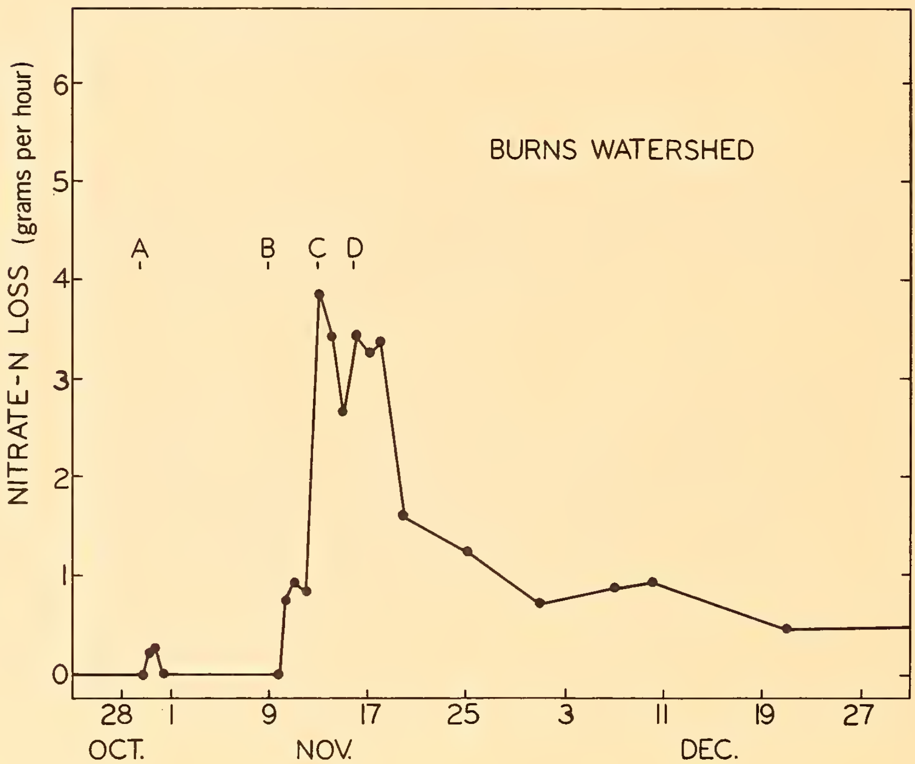
No ammonia-N (detection limit 0.2 parts per million) or urea-N was detected in the Burns Creek sampling. The load of debris in the stream channel was apparently sufficient to remove all of the ammonia-N. Associated with the first fertilization period on Burns Creek watershed October 30-31, nitrate-N transported by streamflow increased to a maximum level of 0.29 grams per hour (5 parts per billion) at 0900 hours, October 31 (fig. 3). Nitrate-N in the streamflow returned to nondetectable levels at 2100 hours, October 31 and remained there until 2100 hours, November 10. Associated with the second period of fertilization November 9-12, the nitrate-N increased to 3.86 grams per hour (68 parts per billion concentrate) on November 13. Streamflow during the period of October 30 to December 31 ranged from 13.9 to 17.5 liters per second (0.49 to 0.62 cubic foot per second). No large changes in streamflow volume were noted in Burns Creek during the observation period. For the period October 30 to December 31, 1.45 kilograms of nitrate-N was estimated to have been carried by streamflow from the Burns Creek watershed.

SUMMARY AND CONCLUSIONS

Nitrogen carried by streamflow was monitored for 60 days following the fertilization of two watersheds with urea and with ammonium sulfate at the rate of 55 kilograms of N per hectare. A third watershed was the unfertilized control. Small amounts of urea-N and nitrate-N found in water from the fertilized watersheds contrasted with none in the control stream. The highest concentration of nitrate-N measured was 210 parts per billion.

The urea appeared to be from fertilizer falling directly into the stream water. The reason for the rapid increase in nitrate-N concentration in the stream is unknown. The apparent conversion from urea and ammonium sulfate to nitrate-N as monitored in this study is much faster than that shown to occur in soils (McLaren 1970), particularly at 5° C. stream temperature. Future research is needed on this phenomenon.

Figure 3.--*Streamflow nitrate-nitrogen loss from Burns Creek watershed after fertilization with 157.9 metric tons of ammonium sulfate.* A *and* B, *first and second period of fertilization;* C, *period of highest loss; and* D, *secondary peak loss associated with precipitation activity.*



With the spring snowmelt and consequent increase in stream volume, additional nitrogen may be carried with sediments and lost from the watershed. A very small nitrogen loss from soil leaching is expected, particularly with the low soil nitrogen and high soil surface carbon levels following fire.

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